Avionics Health Management

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NASA Marshall Space Fight Center/
Integrated System Health Engineering and Management (ISHEM) Workshop
10 November 2005

Agenda

- **Avionics Overview**
  - Functional Components
  - System Architectures
- **Avionics Technology**
- **EEE Parts Classes**
- **Avionics Environments**
- **Failure Sources**
- **Current Avionics Health Management Techniques**
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  - System Level
- **Avionics Health Management Requirements**
- **Proactive Health Management and Recovery**
- **Summary**

Avionics Overview

- **Avionics consists of Electrical, Electronic, Electromechanical (EEE) and software to perform management of vehicle functions**

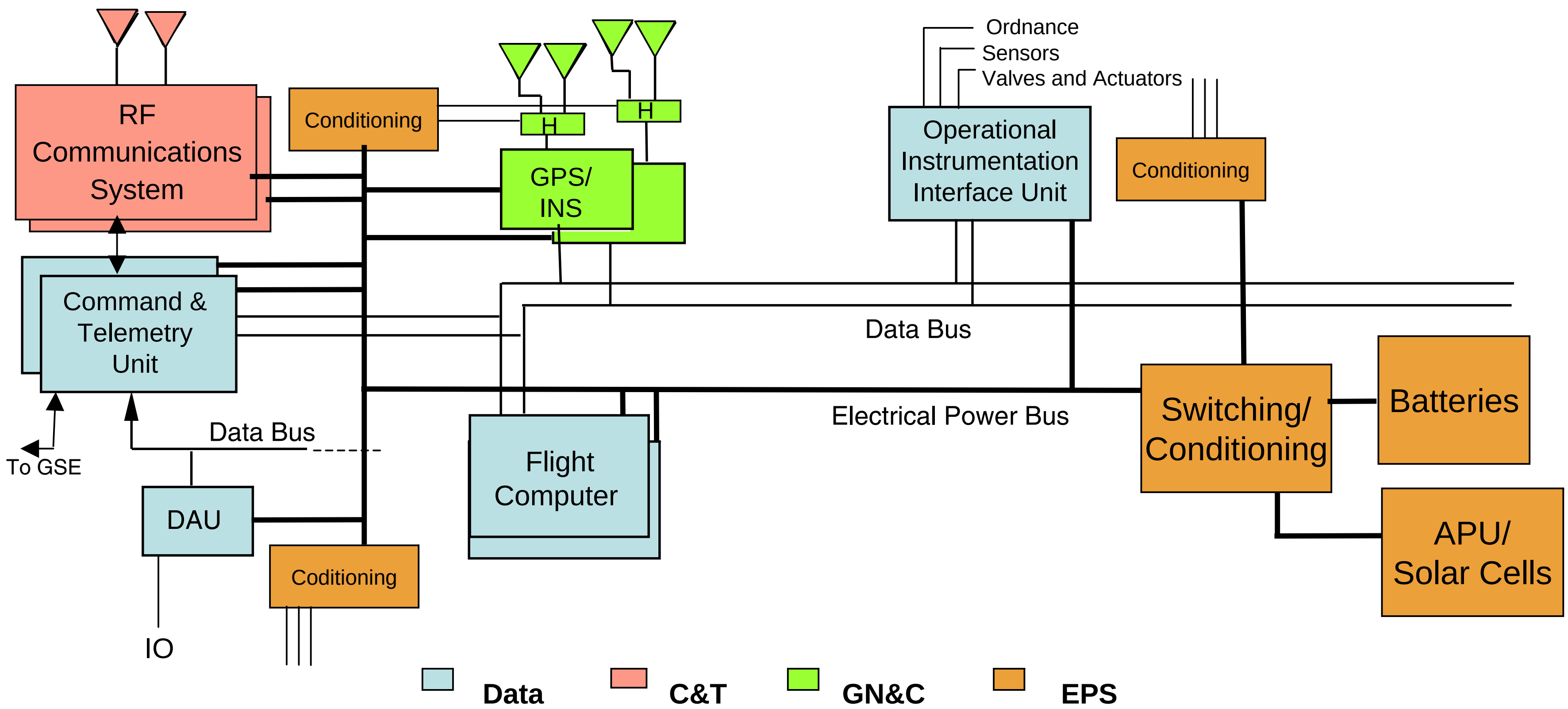
- **Avionics Components**
  - Data Processors
  - Data Busses/Networks
  - Software
    - Performance Management
    - Health Management
    - Communication
  - Guidance, Navigation, and Control (GN&C)
  - Communications and Tracking (C&T)
  - Sensors and Instrumentation
  - Electrical Power System (EPS)

Avionics Overview

- **Avionics Architecture**
  - Federated Systems
    - Integrated but dissimilar components
    - Components viewed as independent elements
    - Integration is focused on interfaces
      - Communication Protocol
      - External Message Passing
    - Fault detection/management internal to component

  - Modular Integrated Systems
    - Tightly integrated components
    - Interchangeable functions across components
    - Integration moves beyond interfaces to functional distribution
    - Fault detection/management at the system level

Avionics Overview



Avionics Technology

- **Digital Electronics**
  - Processors
  - Microcontrollers
  - Field Programmable Gate Arrays (FPGA)
  - Data Busses/Networks
- **Analog Electronics**
  - Data Signal Conditioning (Control Electronics)
    - Sensors
    - Actuators
  - Power Electronics
- **Radio Frequency Electronics**
  - Communications
  - Global Positioning System
  - Wireless data Busses/Electronics
- **Optical Systems**
  - Optical Rotation Rate Sensors (Gyroscopes)
  - Video
  - Optical Sensing
- **Micro Electro-Mechanical Systems (MEMS)**
  - Sensors
  - Accelerometers

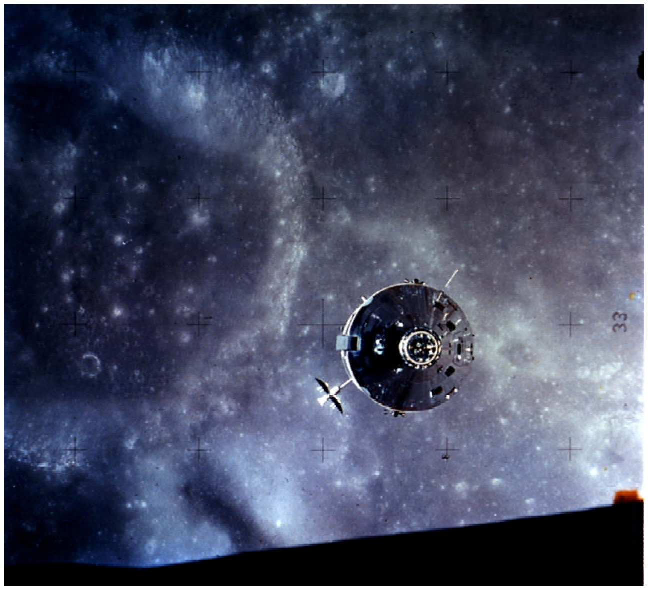
Electrical, Electronic, Electromechanical (EEE) Parts Classes

Grade	Summary	Reliability	MTBF	Cost	Typical Use
Space	"Space" quality class qualified parts, or equivalent.	Highest	Longest	Very High	Human and/or long duration space flight
Military	"Full Military" quality class qualified parts, or equivalent.	Very High	Very Long	High	Space flight, Military Aviation, Commercial Aviation, or critical ground support equipment
Industrial	"Low Military" quality class parts, and Vendor Hi-Rel or equivalent.	High	Long	Moderate	Space flight experiments, Commercial Aviation, and ground support
Commercial	“Commercial" quality class parts. No qualification required.	Variable	Variable	Low	Aviation flight experiments and ground support

Avionics Environments

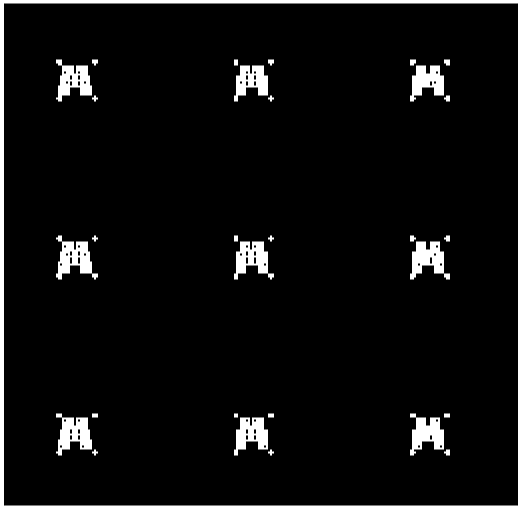
- ♦ **Parameters**
  - Temperature
  - Humidity
  - Pressure
  - Shock and Vibration
  - Electrical
  - Radiation
  - Dust

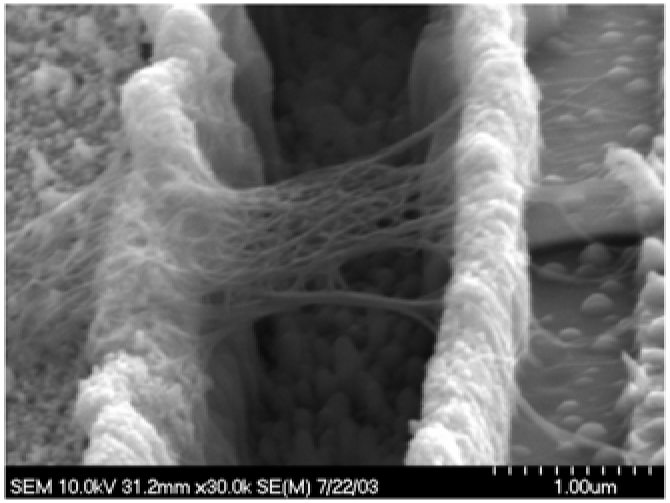
- ♦ **Environmental Regimes**
  - Ground
  - Aviation
  - Space



Failure Sources

- **Environment**
  - Internal
  - External
- **Design Faults**
- **Material Defects**
- **Fabrication**
- **Unexpected System Interactions**





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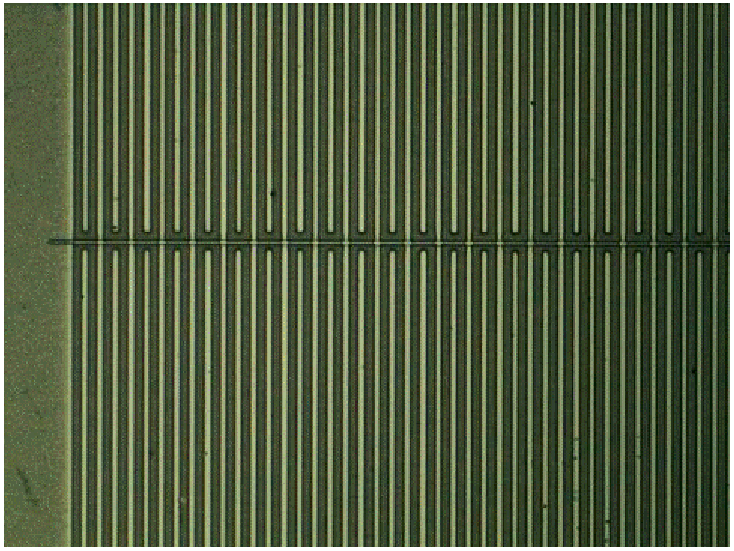
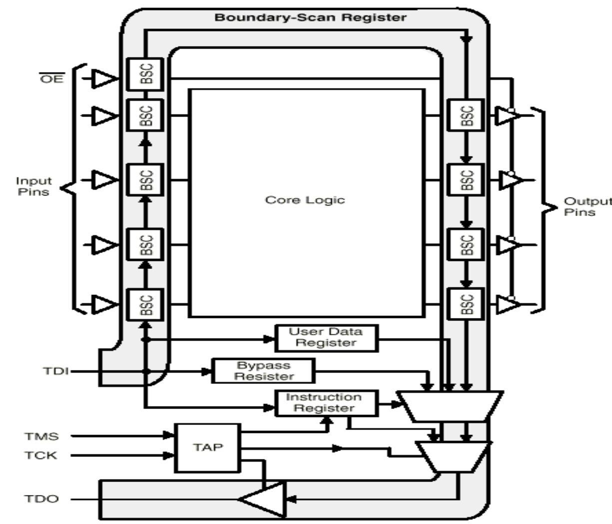
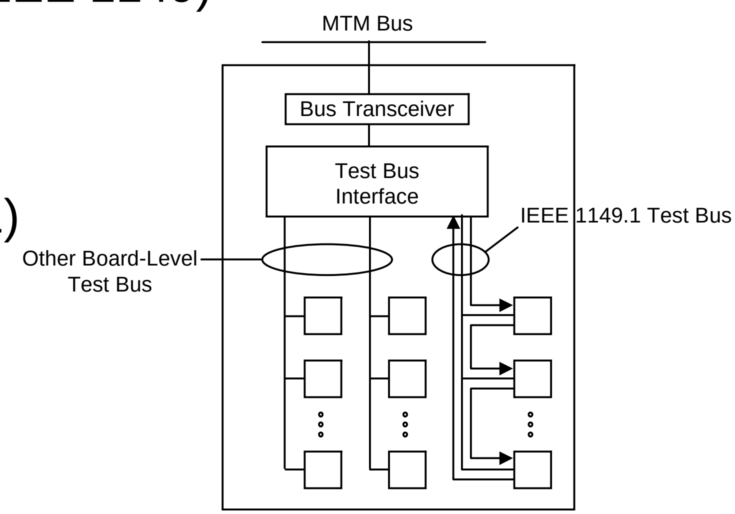


Current Avionics Health Management Techniques

- Current avionics fault detection and protection techniques can be grouped in three classes:
  - Component Level
  - Board Level
  - System Level



- Component Level
  - Built-In-Test (BIT)/Built-In-System-Test (BIST)
  - Error Detection and Correction (EDAC)
  - Boundary Scan (IEEE 1149)
  - Module Test and Maintenance Bus (MTM) (IEEE 1149)
  - Voting
  - Idle Data Pattern Diagnosis
  - Input Protection
  - Intelligent Sensors and Actuators (IEEE 1451)



Current Avionics Health Management Techniques

- **System Level**
  - A variety of standards to facilitate generation and collection of integrated system data have been/are being development which support Avionics Health Management capabilities
    - Artificial Intelligence Exchange and Service Tie to All Test Environments (AI-ESTATE) (IEEE 1232)
    - Open System Architecture-Condition Based Maintenance (OSA-CBM)
      - Extensible Mark-up Language (XML)
      - Common Object Request Broker Architecture (CORBA)
      - Component Object Model/Distributed Component Object Model (COM/DCOM)
    - Automatic Test Meta Language (ATML)
    - Open System Architecture for Enterprise Application Integration (OSA-EAI)
    - Predictive Model Markup Language (PMML)
  - Key attributes of system level capabilities include
    - Continual learning
    - System Assessment
    - Hidden Data Pattern Discovery
  - Diagnostics are more mature than Prognostics
    - Rule-Based and Model-Based Reasoners are the most mature technologies for interpreting system data and discovering hidden data patterns
    - Feature Based Approaches show promise
      - Neural Networks
      - Fuzzy Logic
      - Requires a strong understanding of system nominal and off nominal behaviors
        - Test data essential

Avionics Health Management Logistics Support

- Avionics Health Management can move logistics support from 3 level to 2 level systems be redistributing intermediate maintenance functions to either the field or depot

Operational Level	Intermediate Level	Depot Level
▪ Schedule-based prescribed inspections and service of aircraft, systems, and subsystems as detailed in the aircraft's Maintenance Requirement Cards and Maintenance Plan ▪ Corrective Maintenance performed using BIT and other o-level data to isolate defective LRUs ▪ Repairs made to powerplants, airframes, aircraft wiring, and connectors ▪ Forward defective LRUs to the Intermediate Maintenance Activity for repair	▪ LRU performance verified by the appropriate ATE ▪ Verify faulty LRUs and isolate to a faulty Shop Replaceable Assembly (SRA), or component, using ATE ▪Test, repair, calibration, and modification of the aircraft, systems, and subsystems ▪ Disposition of assets from stricken aircraft ▪ Faulty SRUs removed, repaired, and replaced ▪Repair and calibration of support equipment	▪ Maintenance preformed at industrial establishments to ensure continued flying integrity of airframes and flight systems during subsequent operational service periods ▪ Depot level maintenance actions requiring repair, major overhaul, or a complete rebuilding, manufacture, or modification of parts, assemblies, sub-assemblies, and end items beyond the capabilities of intermediate level maintenance

Benefits - ***Reduction in total life cycle cost***

- *Decreased Logistics Footprint*
- *Decreased Procurement Cost*
- *Decreased spares costs*
- *Less Transportation and Storage*
- *Better Calibration support and Training*
- *Improved Readiness*

Avionics Health Management Requirements

- **Requirements for Avionics Health Management have two drivers**
  - Environment
  - Dependency of human health and safety on the system
    - Human Interaction
      - Human health and safety is dependent on human interactions with the system
        - Display Management
        - Manual Control Interfaces
    - Human Life Support
      - Human dependence on system for survivability
      - Loss of system means loss of life
- **These drivers affect the different regimes differently**
  - Space
    - Human Interaction required during critical operations
      - Limited or no options for system recovery
    - Human Life Support supplied by the spacecraft
    - Human survivability totally dependent on the spacecraft
    - Robotic spacecraft have no human interaction or dependence requirements
  - Aviation
    - Human Interaction required during critical operations
      - Limited system recovery operations
    - Human Life Support
      - Required for high altitude aircraft
      - Partially required at intermediate altitudes (pressure and temperature)
      - Not required at low altitudes
    - Unmanned Aerial Vehicles (UAV) have no interaction or dependence requirements
  - Industrial
    - Human Interaction
      - Application dependent
      - Critical Applications
        - Nuclear Power Plants
        - Petroleum/Chemical Plants
    - Human Life Support
      - Not dependent in most cases

Proactive Health Management and Recovery

- **Current Systems are reactive**
  - Responds after failures
    - – Redundancy is a reactive capability
- **Systems need to take a proactive response to Avionics Health Management**
  - Error and Fault Detection
    - – Real-time logic checking (proactive)
    - – Vector Testing (reactive)
    - – Idle Data Pattern Diagnosis (reactive)
    - – Ground Plane Frequency Diagnosis (proactive/reactive)
  - Recovery
    - – System Reset (reactive)
    - – Redundancy (reactive/proactive)
      - Similar
      - Dissimilar
      - Redistribution
    - – Reconfigurable Computing (proactive/reactive)

Summary

- **Avionics employs a diverse set of electrical, electronic, electromechanical, and optical technologies**
  - EEE Parts Classes effect reliability/durability
- **Avionics Environments are diverse and vary greatly from aviation to space**
- **Failure Sources**
  - Environmental
  - Design
  - Materials
  - Fabrication
  - System Interactions
- **Current Avionics Health Management Techniques**
  - Component Level technologies based on off-line maintenance techniques
  - System Level technologies are maturing and offer great promise
- **Avionics Health Management Requirements**
  - Human dependence is strong driver on systems
- **Proactive Health Management and Recovery**
  - Many techniques are reactive
  - Proactive techniques are much more difficult to achieve